High energy deficit in an ultraendurance athlete in a 24-hour ultracycling race

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Abstract: This case study examined the nutritional behavior and energy balance in an official finisher of a 24-hour ultracycling race. The food and beverages consumed by the cyclist were continuously weighed and recorded to estimate intake of energy, macronutrients, sodium, and caffeine. In addition, during the race, heart rate was continuously monitored. Energy expenditure was assessed using a heart rate-oxygen uptake regression equation obtained previously from a laboratory test. The athlete (39 years, 175.6 cm, 84.2 kg, maximum oxygen uptake, 64 mL/kg/min) cycled during 22 h 22 min, in which he completed 557.3 km with 8760 m of altitude at an average speed of 25.1 km/h. The average heart rate was 131 beats/min. Carbohydrates were the main macronutrient intake (1102 g, 13.1 g/kg); however, intake was below current recommendations. The consumption of protein and fat was 86 g and 91 g, respectively. He ingested 20.7 L (862 mL/h) of fluids, with sport drinks the main fluid used for hydration. Sodium concentration in relation to total fluid intake was 34.0 mmol/L. Caffeine consumption over the race was 231 mg (2.7 mg/kg). During the race, he expended 15,533 kcal. Total energy intake was 5571 kcal, with 4058 (73%) and 1513 (27%) kcal derived from solids and fluids, respectively. The energy balance resulted in an energy deficit of 9915 kcal.

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High energy deficit in an ultraendurance athlete in a 24-hour ultracycling race

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This case study examined the nutritional behavior and energy balance in an official finisher of a 24-hour ultracycling race. The food and beverages consumed by the cyclist were continuously weighed and recorded to estimate intake of energy, macronutrients, sodium, and caffeine. In addition, during the race, heart rate was continuously monitored. Energy expenditure was assessed using a heart rate–oxygen uptake regression equation obtained previously from a laboratory test. The athlete (39 years, 175.6 cm, 84.2 kg, maximum oxygen uptake, 64 mL/kg/min) cycled during 22 h 22 min, in which he completed 557.3 km with 8760 m of altitude at an average speed of 25.1 km/h. The average heart rate was 131 beats/min. Carbohydrates were the main macronutrient intake (1102 g, 13.1 g/kg); however, intake was below current recommendations. The consumption of protein and fat was 86 g and 91 g, respectively. He ingested 20.7 L (862 mL/h) of fluids, with sport drinks the main fluid used for hydration. Sodium concentration in relation to total fluid intake was 34.0 mmol/L. Caffeine consumption over the race was 231 mg (2.7 mg/kg). During the race, he expended 15,533 kcal. Total energy intake was 5571 kcal, with 4058 (73%) and 1513 (27%) kcal derived from solids and fluids, respectively. The energy balance resulted in an energy deficit of 9915 kcal.

Ultraendurance competitions are held as solo events in an attempt to challenge the limits of human endurance. These events are defined as an endurance performance of more than 6 hours (1). Careful race preparation is mandatory for all competitors, and the successful accomplishment of such a race depends on many factors, among which nutrition is one of the most important. Adequate nutritional intake is important not only to maintain or improve performance but also to avoid disturbances in the athletes' health. Several studies have reported on the nutritional behavior and demands of cyclists during ultraendurance competitions of several days, such as the Race Across America (2, 3). However, only one case study published in the 1980s has examined the nutritional demands and nutritional behavior of cyclists during events lasting for 24 hours (4). The popularity of these competitions during the past few years has become evident, and with the increase in the number of competitions, information is needed on the nutritional demands in these events (5). Accordingly, the aim of this case study was to describe the nutritional behavior (ingestion of macronutrients, fluids, sodium, and caffeine) and to assess the energy balance of one cyclist during a 24-hour ultracycling race.

METHODS

Participant and race

The physical and physiological characteristics of the cyclist are shown in *Table 1.* Before testing, the participant was informed of the risks associated with the study and provided written informed consent in accordance with the local ethical committee.

The race consisted of completing the greatest possible distance during 24 hours (from 7:00 PM on July 3, 2009, through

Table 1. Physical and physiological characteristics of the cyclist

Variable	Value
Age (years)	39
Height (cm)	175.6
Body mass (kg)	84.2
Body mass index (kg/m^2)	26.4
Body fat (%)	11.6
VO_{2max} (mL/kg/min)	64.0
W_{max} (watts/kg)	5.5
HR_{max} (beats/min)	199
VT HR (beats/min)	159
RCP HR (beats/min)	173

VO_{2max} indicates maximum oxygen uptake; W_{max}, maximum power output relative to body mass in watts; HR_{max}, maximum heart rate; VT HR, heart rate at ventilatory threshold; RCP HR, heart rate at respiratory compensation point.

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7:00 PM on July 4) on a closed-road circuit that was 3790 m in length and 60 m of elevation per lap. The time and velocity to complete each lap was recorded. During the race, the ambient air temperature was 27.5°C (range, 24.6–31.0); the relative humidity, 53.9% (range, 33.0–72.0); and the mean velocity of wind, 1.7 m/s (range, 0.6–3.0).

Preliminary testing

One week before the competition, the athlete reported to a physiology laboratory under controlled conditions (22 ± 1°C, 40%–60% relative humidity, 760–770 mm Hg) to perform an incremental maximum oxygen uptake (VO_{2max}) test. The test was performed on an electronically braked cycle ergometer (Excalibur Sport, Lode, The Netherlands) modified with clip-on pedals. The exercise protocol started at 25 watts and was increased 25 watts every minute until exhaustion. The number of revolutions was individually chosen in the range of 70 to 100 revolutions per minute. During the test, the respiratory response was measured, breath by breath, using a computerized gas analyzer (Cosmed Quark PFT Ergo, Italy). Before the test, the ambient condition was measured and the gas analyzers and inspiratory flowmeter were calibrated using high-precision calibration gases (16.00 ± 0.01% O_2 and 5.00 ± 0.01% CO_2; Scott Medical Products, USA). After the test, all respiratory data were averaged at 30-second intervals to determine VO_{2max}, taken as the highest average value. In addition, heart rate (HR) was continuously recorded using a portable HR monitor (Polar RS800 SD, Finland). HR_{max} was defined as the HR at the point of exhaustion.

Data collection during the race

Within the circuit, all the athletes had a box where they could stop during racing to recover, sleep, eat, and repair bicycle breakdowns. In the other points of the circuit, riders could not receive any assistance. Nutritional data were collected by four trained investigators who remained in the box of the rider, weighing and recording all the food and fluid ingested. Nutritional data were analyzed for nutrient composition using nutritional software (CESNID 1.0, Barcelona University, Spain). Information about the nutritional content of foods not available in the computer program was obtained from the manufacturer. All the food was weighed on a digital scale (Soehnle 8020, Spain) with a precision of 1 g increments up to 1 kg and 2 g between 1 and 2 kg. We divided the input of energy derived from solid and liquid food, classified as products that did not need mastication.

In addition, during the competition, HR was continuously monitored, beat by beat, using a portable HR monitor (Polar RS800 SD, Finland) that was properly programmed with gender, age, and weight following the manufacturer's instruction. Later, all HR data were averaged at 10-second intervals. The linear relationship between HR and VO_2 obtained during the laboratory test was used to estimate the oxygen costs and energy expenditure of racing (r^2 = 0.988). Taking the average of HR during the competition and the maximal HR obtained during the laboratory test, we calculated the ratio of HR_{mean}/HR_{max}.

RESULTS

The cyclist successfully completed the race, cycling for 22 h 22 min, in which he completed 557.3 km with 8760 m of altitude at an average speed of 25.1 km/h, finishing in third place. He reported no gastrointestinal disturbances during the race. The average HR during the event was 131 beats/min, with a ratio of HR_{mean}/HR_{max} of 0.69. He made a total of seven stops lasting 1 h 38 min. During the race, he expended 15,533 kcal of energy, corresponding to 647 kcal/hour.

As shown in Table 2, during the event, solid foods provided 73% (4058 kcal) of the total energy, and the remaining 27% (1513 kcal) was provided by fluids such as sport drinks. Carbohydrates were the main macronutrient he ingested (1102 g; 13.1 g/kg). Overall consumption of fluids and sodium during the event was 20.7 L (862 mL/h) and 16,182 mg (34.0 mmol/L), respectively. Fluids comprised 86% (13,878 mg) of the total sodium intake, and solids comprised 14% (2355 mg). During the second half of the event (7–19 h), the cyclist increased consumption of caffeinated drinks, with total caffeine intake of 231 mg (2.7 mg/kg); consumed low amounts of branched chain amino acids in pill form during the rest periods; and ingested one ibuprofen pill after 9 h of competition and two aspirin pills at 18 h.

After the event, the athlete lost 2.6 kg of total body mass (prerace, 84.2 kg; postrace, 81.6 kg). A total deficiency of 9915 kcal resulted after the race, so that a higher proportion (64%) of energy was obtained from endogenous fuel stores.

DISCUSSION

The main finding of this study was the high energy deficit of this cyclist. He ingested only 36% of the energy expended through the event, thus providing the remaining 64% of the energy from endogenous fuel stores. To the best of our knowledge, these data represent the highest energy deficit reported in ultraendurance events of 24 hours or longer. Previous studies showed an energy intake and expenditure ratio between 0.50 and 0.65 (2, 4, 6).

However, it is worth mentioning that the method used in this study to estimate energy expenditure (relationship between HR and VO_2) has several limitations. For instance, during longer events, HR can be influenced by environmental conditions such as temperature and humidity, which can favor dehydration and an increase of HR without associated changes in VO_2 (7). Currently, the method of doubly labeled water is considered the reference method to estimate energy expenditure. Another feasible method to estimate energy expenditure in cycling is the analysis of power output (8). However, neither of these methods was at our disposal during the current study. For this reason and similar to other recent studies (6, 9–11), we estimated energy expenditure using the HR-VO_2 method. Compared with the doubly labeled water method, this method is inexpensive and easy to perform. Additionally, monitoring of HR also provides information on the amount of time spent at different levels of exercise intensity, which may also be useful for the assessment of physical activity rather than energy expenditure. Furthermore, it has been reported that energy expenditure estimated using the

Table 2. Nutritional analysis of foods and fluids ingested by the cyclist during the event

Variable	0–6 h	6–12 h	12–18 h	18–24 h	Total
Ingested					
Solid food (g)					
Pasta with olive oil	–	224	133	200	557
Sport bars	252	137	101	65	555
Fruit	–	513	–	243	756
Chicken	–	–	–	70	70
Cured ham	–	–	43	–	43
Bread	–	–	40	–	40
Fluids (mL)					
Sport drinks (0% carbohydrate)	–	–	2292	5714	8006
Sport drinks (1.4% carbohydrate)	1806	1830	1279	–	4915
Sport drinks (7% carbohydrate)	–	–	–	3080	3080
Water	1241	932	–	–	2173
Caffeinated drinks	–	250	330	580	1160
Water in food	8	601	178	365	1152
Juice	–	250	–	–	250
Supplementation and medication					
Branched chain amino acids (mg)	–	–	1000	1500	2500
Ibuprofen (mg)	–	–	600	–	650
Aspirin (mg)	–	–	–	200	200
Analysis					
Energy (kcal)					
Solids	1357	918	675	1108	4058
Fluids	121	211	388	793	1513
Total	1478	1129	1063	1901	5571
Carbohydrates (g)					
Solids	260	164	106	192	722
Fluids	28	52	102	198	380
Total	288	216	208	390	1102
Percent of total energy	77.9	76.5	78.3	82.1	79.1
g/min	0.8	0.6	0.6	1.1	0.8
Protein (g)					
Solids	23	19	15	29	86
Percent of total energy	6.2	6.7	5.6	6.1	6.2
Carbohydrate/protein ratio	12.5	11.4	13.9	13.4	12.8
Fat (g)					
Solids	26	21	19	25	91
Percent of total energy	15.6	16.7	16.1	11.8	14.7
Caffeine (mg)	–	82	35	113	231
Sodium (mg)	2201	2101	4752	7128	16,182

HR method compared with the method of doubly labeled water is overestimated by ~10% (12). If we accounted for this by reducing the energy expenditure estimated in this study by 10%, the energy deficit would be decreased only 4%, from 64% to 60%. Therefore, although the doubly labeled water method could be used under field conditions, the high cost and the inability to obtain an activity pattern does not always make it ideal.

Based on the athlete's average intensity of 69% HR_{max}, it is estimated that approximately two thirds of the total energy required was met by fat oxidation, with carbohydrate oxidation providing one third (13). However, fat oxidation is not a limitation for providing fuel during longer events (13, 14). The estimation of anthropometric characteristics in the current athlete indicated that he had ~9.8 kg of subcutaneous adipose tissue that could provide >88,000 kcal. Based on that, the athlete should consume a high amount of carbohydrates during the event due to his limited glycogen stores (13). The recommended amount of carbohydrate intake to optimize the oxidation rates has been reported to be between 1.0 and 1.2 g/min (15). The current athlete ingested amounts of carbohydrates below these recommendations during three-quarters of the event; only during the last 6 h, when fatigue symptoms were more pronounced and the glycogen stores were possibly depleted, did he meet the carbohydrate consumption threshold of >1.0 g/min.

Additionally, although protein is not considered a primary energy source for athletes, it has been suggested to play an important role during longer events. An adequate ratio of carbohydrate/protein may reduce a negative protein balance (16, 17) and may enhance aerobic endurance performance (18).

An optimal rate (g) between carbohydrate and protein intake seems to be 4:1 (18). Applying these recommendations in the present case study, and assuming that the athlete had ingested the recommended carbohydrate rate (~1.1 g/min), protein intake would have had to have been ~400 g (4.7 g/kg of body mass), representing more than threefold the actual amount of protein intake by the cyclist during the event. Accordingly, this amount of protein seems to be excessive and, independent of the supposed benefits of carbohydrate and protein combination, it should also be taken into account that protein intake is associated with greater satiety and a reduced *ad libitum* energy intake in humans. Thus, higher protein consumption during longer events can be associated with a reduction of food intake, as well as an increase of the risk of gastrointestinal disturbances. Further studies are needed to analyze whether an increase of protein intake above the current recommendations (1.2 –1.7 g/kg of body mass/day) may induce benefits in longer and high-intensity sport events.

Furthermore, the hydration pattern is one of the nutritional keys in ultraendurance events. While the current athlete ingested the high amount of 20.7 L of fluids during the race, the hydration strategy was not in agreement with current recommendations (19, 20). He should have prioritized the consumption of isotonic fluids containing carbohydrates (sucrose, maltose, or maltodextrins) at ~3% to ~8% weight/volume during the race (21). Thus, the strategy of hydration followed by the cyclist substantially reduced the amount of carbohydrate intake. If he had prioritized the consumption of isotonic fluids (7% of carbohydrates), he would have obtained ~900 g extra carbohydrates, reaching values within the carbohydrate recommendations for longer events (15).

Related to the hydration pattern, one of the most common medical complications during long-distance events is exercise-associated hyponatremia (22), defined as a serum plasma or sodium concentration <135 mmol/L^{-1}. To prevent exercise-associated hyponatremia, the athlete ingested higher amounts of sodium, mainly during the second half of the event when the environmental conditions were harsher. Nevertheless, although some hydration guidelines recommend consuming fluids with a high content of sodium (30–50 mmol/L) (21), currently there is insufficient evidence to determine whether sodium intake prevents or decreases the risk of exercise-associated hyponatremia (23). On the contrary, some risks of excessive sodium supplementation in combination with overhydration have been documented (24). There are at least two ways to reduce the risk of excessive fluid retention: 1) drink only according to thirst and 2) monitor body weight so as to avoid weight gain during exercise. In the present study, the cyclist showed no weight gain; he lost 2.6 kg of body mass over the race. However, in ultraendurance events such as an Ironman triathlon, it has been reported that part of fluid losses, at least 2 kg, could be derived from reduction of fat stores, skeletal muscle mass, glycogen, and the metabolic water stored in glycogen (25, 26).

In conclusion, this case study shows one of the highest energy deficits in the scientific sports literature. To minimize the energy deficit, athletes should receive nutritional training before the event so that the digestive system can adapt to higher amounts of food and fluids while physical exercise is performed. In addition, they should begin the event with their meals and fluids planned and prepared beforehand according to their preferences. The present findings highlight the importance of the support provided by sports dieticians and sports physiologists in helping athletes plan and monitor their food and fluid intake during longer events.

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1. Zaryski C, Smith DJ. Training principles and issues for ultra-endurance athletes. *Curr Sports Med Rep* 2005;4(3):165–170.
2. Knechtle B, Enggist A, Jehle T. Energy turnover at the Race Across AMerica (RAAM)—a case report. *Int J Sports Med* 2005;26(6):499–503.
3. Lindeman AK. Nutrient intake of an ultraendurance cyclist. *Int J Sport Nutr* 1991;1(1):79–85.
4. White JA, Ward C, Nelson H. Ergogenic demands of a 24 hour cycling event. *Br J Sports Med* 1984;18(3):165–171.
5. Knechtle B, Knechtle P, Lepers R. Participation and performance trends in ultra-triathlons from 1985 to 2009. *Scand J Med Sci Sports* 2011;21(6):e82–e90.
6. Bircher S, Enggist A, Jehle T, Knechtle B. Effects of an extreme endurance race on energy balance and body composition—a case study. *J Sports Sci Med* 2006;5:154–162.
7. Ainslie P, Reilly T, Westerterp K. Estimating human energy expenditure: a review of techniques with particular reference to doubly labelled water. *Sports Med* 2003;33(9):683–698.
8. Atkinson G, Peacock O, St Clair Gibson A, Tucker R. Distribution of power output during cycling: impact and mechanisms. *Sports Med* 2007;37(8):647–667.
9. Stewart IB, Stewart KL. Energy balance during two days of continuous stationary cycling. *J Int Soc Sports Nutr* 2007;4:15.
10. Bourrilhon C, Philippe M, Chennaoui M, Van Beers P, Lepers R, Dussault C, Guezennec CY, Gomez-Merino D. Energy expenditure during an ultraendurance alpine climbing race. *Wilderness Environ Med* 2009;20(3):225–233.
11. Rejc E, Lazzer S, Antonutto G. Energy expenditure and dietary intake of athletes during an ultraendurance event developed by hiking, cycling and mountain climbing. *J Sports Med Phys Fitness* 2010;50(3):296–302.
12. Livingstone MB, Coward WA, Prentice AM, Davies PS, Strain JJ, McKenna PG, Mahoney CA, White JA, Stewart CM, Kerr MJ. Daily energy expenditure in free-living children: comparison of heart-rate monitoring with the doubly labeled water (2H2(18)O) method. *Am J Clin Nutr* 1992;56(2):343–352.
13. Maughan RJ. Nutritional aspects of endurance exercise in humans. *Proc Nutr Soc* 1994;53(1):181–188.
14. Laursen PB, Ahern SM, Herzig PJ, Shing CM, Jenkins DG. Physiological responses to repeated bouts of high-intensity ultraendurance cycling—a field study case report. *J Sci Med Sport* 2003;6(2):176–186.
15. Jeukendrup AE. Carbohydrate intake during exercise and performance. *Nutrition* 2004;20(7–8):669–677.
16. Koopman R, Pannemans DL, Jeukendrup AE, Gijsen AP, Senden JM, Halliday D, Saris WH, van Loon LJ, Wagenmakers AJ. Combined ingestion of protein and carbohydrate improves protein balance during ultra-endurance exercise. *Am J Physiol Endocrinol Metab* 2004;287(4):E712–E720.

17. Beelen M, Tieland M, Gijsen AP, Vandereyt H, Kies AK, Kuipers H, Saris WH, Koopman R, van Loon LJ. Coingestion of carbohydrate and protein hydrolysate stimulates muscle protein synthesis during exercise in young men, with no further increase during subsequent overnight recovery. *J Nutr* 2008;138(11):2198–2204.
18. Ivy JL, Res PT, Sprague RC, Widzer MO. Effect of a carbohydrate-protein supplement on endurance performance during exercise of varying intensity. *Int J Sport Nutr Exerc Metab* 2003;13(3):382–395.
19. Peters EM. Nutritional aspects in ultra-endurance exercise. *Curr Opin Clin Nutr Metab Care* 2003;6(4):427–434.
20. American College of Sports Medicine, Sawka MN, Burke LM, Eichner ER, Maughan RJ, Montain SJ, Stachenfeld NS. American College of Sports Medicine position stand. Exercise and fluid replacement. *Med Sci Sports Exerc* 2007;39(2):377–390.
21. Rehrer NJ. Fluid and electrolyte balance in ultra-endurance sport. *Sports Med* 2001;31(10):701–715.
22. Rosner MH, Kirven J. Exercise-associated hyponatremia. *Clin J Am Soc Nephrol* 2007;2(1):151–161.
23. Hew-Butler T, Ayus JC, Kipps C, Maughan RJ, Mettler S, Meeuwisse WH, Page AJ, Reid SA, Rehrer NJ, Roberts WO, Rogers IR, Rosner MH, Siegel AJ, Speedy DB, Stuempfle KJ, Verbalis JG, Weschler LB, Wharam P. Statement of the Second International Exercise-Associated Hyponatremia Consensus Development Conference, New Zealand, 2007. *Clin J Sport Med* 2008;18(2):111–121.
24. Luks AM, Robertson HT, Swenson ER. An ultracyclist with pulmonary edema during the Bicycle Race Across America. *Med Sci Sports Exerc* 2007;39(1):8–12.
25. Speedy DB, Noakes TD, Kimber NE, Rogers IR, Thompson JM, Boswell DR, Ross JJ, Campbell RG, Gallagher PG, Kuttner JA. Fluid balance during and after an Ironman triathlon. *Clin J Sport Med* 2001;11(1):44–50.
26. Knechtle B, Baumann B, Wirth A, Knechtle P, Rosemann T. Male Ironman triathletes lose skeletal muscle mass. *Asia Pac J Clin Nutr* 2010;19(1):91–97.